Common Aperture EO-RF Antena
Phase II SBIR Contract Number F33615-03-C-1450
Lt. Shawn Willis AFRL/SNJM

CHORD™

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Mirror Technology Days
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Outline

- Requirements
- Design and Performance
- Hardware

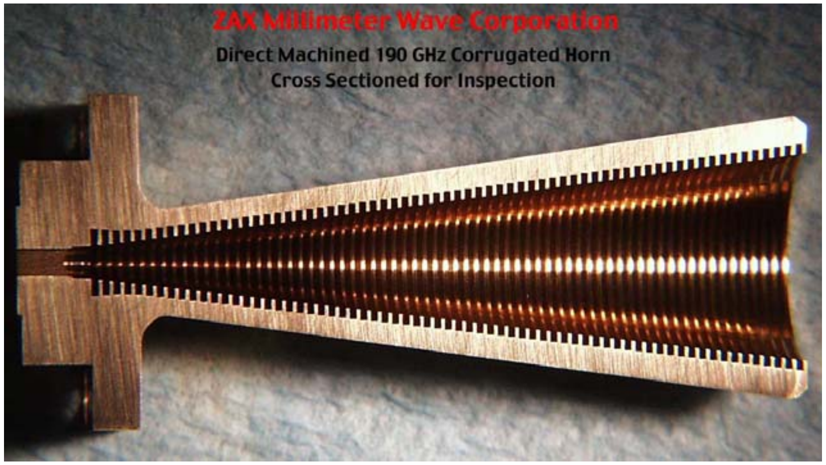
Requirements

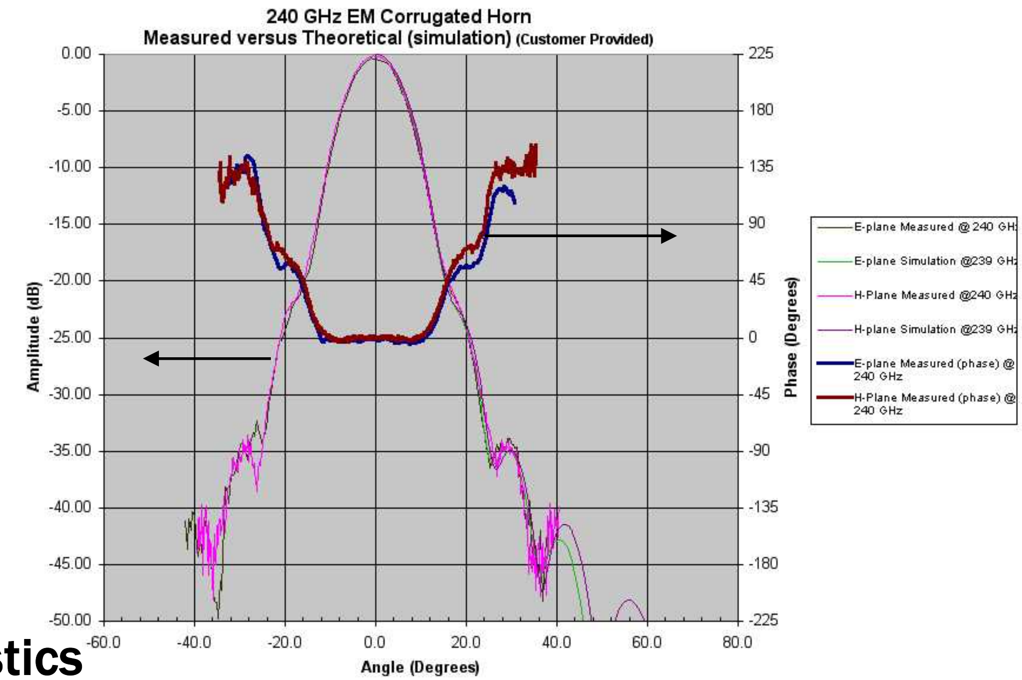
- Technical Requirements
  - ⇒ Deliver 50 cm diameter (5/12 scale model) RF/optical aperture antenna
  - ⇒ Antenna architecture feasibility analysis and trade studies
    - → Aperture subsystem
      - – Provide high precision surface for the laser link
      - – Provide low noise temperature and superior sidelobes for the microwave link
    - → Up- and down-converter subsystems
    - → Digital processing requirements
    - → Beam control for tracking the satellite

Design and Analysis

- Prototype Design
  - ⇒ No formal system requirements
  - ⇒ A Complete Concept Evolution
- Goal to demonstrate Signal Separation in the Laboratory
- Feedhorn parameters form a tradespace
  - ⇒ RF bandwidth, beamwidth to achieve desired illumination on the primary, aperture diameter, length, gain and voltage standing wave ratio (VSWR)
  - ⇒ Signal strength = f(illumination pattern vs gain)
- Selected RF Design Space to generate strong signal
  - ⇒ RF bandwith: 18-36 GHz
  - ⇒ Beamwidth: 60 – 90 degrees
  - ⇒ VSWR: <1.5
  - ⇒ Polarization: Circular or Dual-Linear

RF Feed Horn Point Design





- Circular polarization
- Wideband
- Excellent illumination characteristics

- Baseline Feedhorn:
  - 1 octave bandwidth for 18-36 GHz operation (point or continuous)
  - Beamwidth of 60 degrees
  - Aperture diameter of 60 mm
  - Length of 100 mm
  - Side lobe suppression
  - Low VWSR, standard gain (9 dBi)

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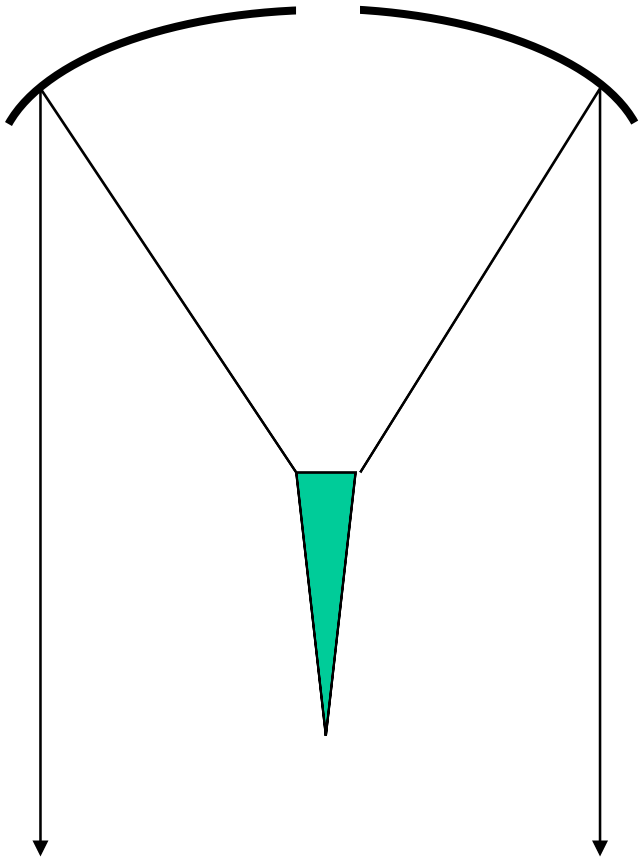
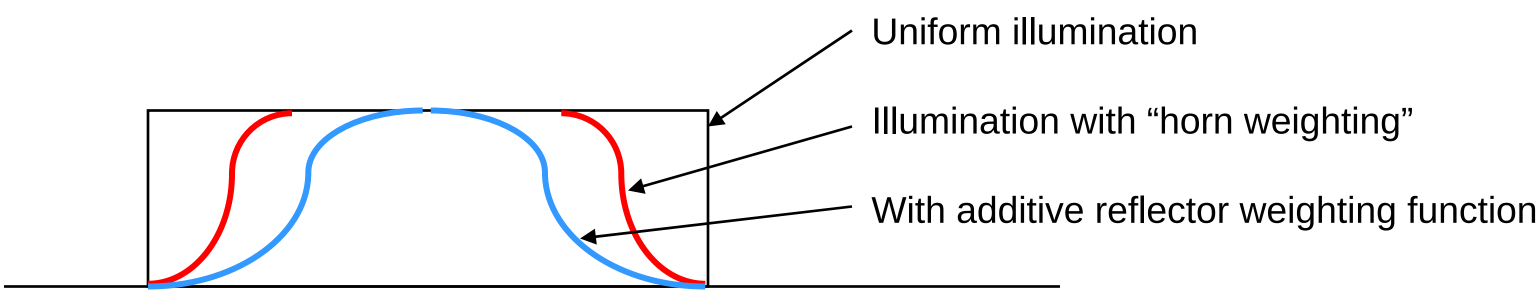
Impact of Aperture Reflectivity and Feed Horn Pattern



Far field RF beam pattern is the Fourier transform (Bessel functions for cylindrical geometry) of the near field illumination pattern

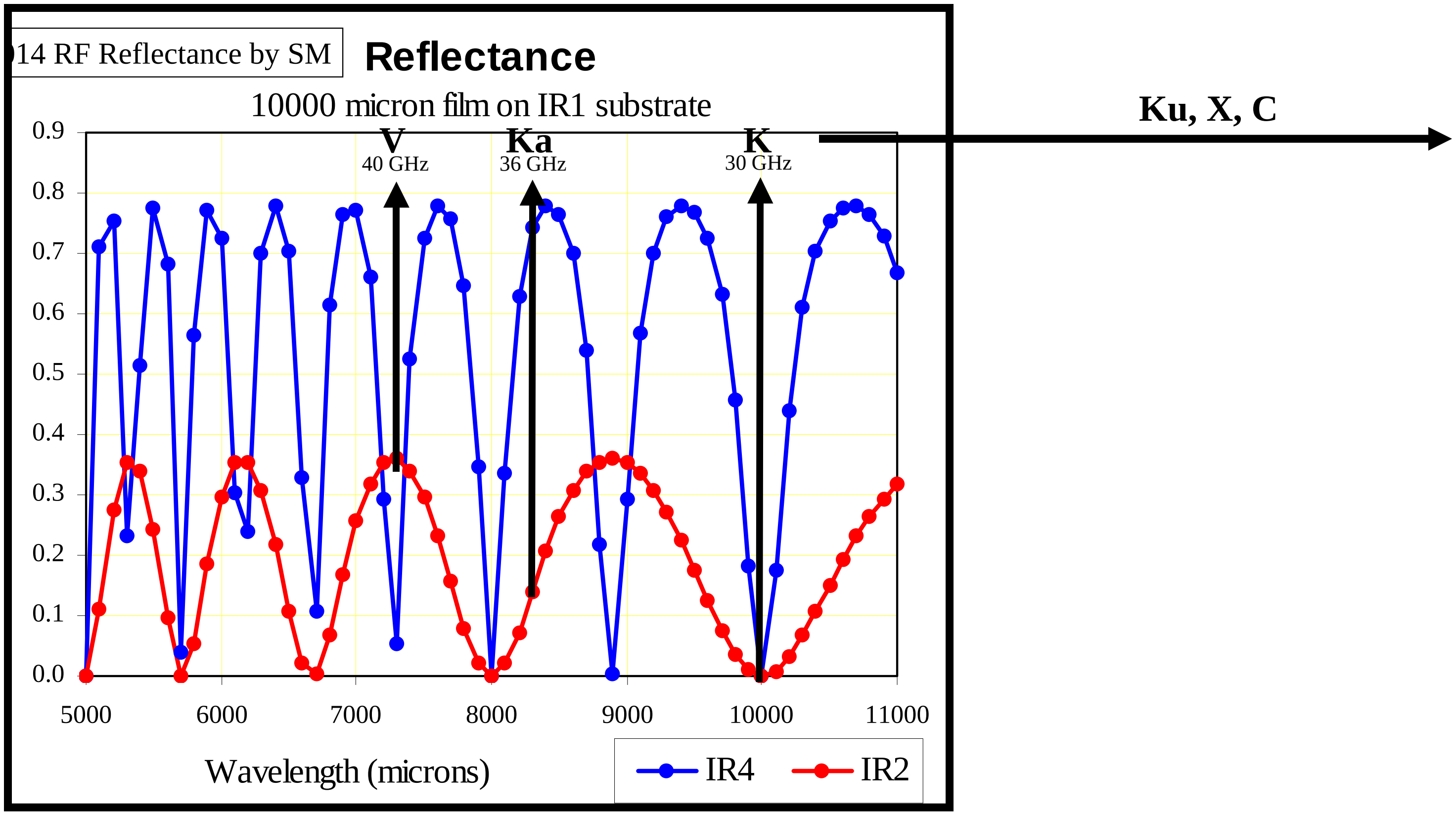
Near field illumination pattern is determined by:
- Illumination pattern of feed horn
- Reflectivity vs angle of the reflector
- Sidelobes in far field controlled by applying a reflective "weighting function" to reflector to improve over basic "horn weighting"

Goal of weighting function is to smooth the transition from the illuminated region to the un-illuminated region outside the reflector—smoother is better!



Frequency Agility

- Evaluated normal incidence RF reflectance for a non-absorbing substrate
  - ⇒ Assumed thick film on a substrate with n=1 (air)
  - ⇒ Evaluated film index of refraction
- Much room for optimization to obtain frequency agility
  - ⇒ Transmission improves in direction of lower frequencies!!!
  - ⇒ >90% transmission for selected uplink/downlink frequencies



Trade Study Parameters

- Data rate
- Aperture sizes
- Laser power
- Link range
- Link margins
- On-board power/weight/volume
  - ⇒ Airborne platform
  - ⇒ Lasercom Satellite Package
- Acquisition time
- On-orbit lifetime
- Bit Error Rate (BER)
- Tracking envelope (jitter, slew)
- Atmospheric path length
- Number of terminals per platform
- Number of aircraft serviced
- Quality of service
  - ⇒ Timeliness
  - ⇒ Applicability
  - ⇒ Availability

Trade Studies Summary

- Antenna design not effected by trade study results
- Future Work
  - ⇒ Point design for optical up- and down-converter subsystem
  - ⇒ Point design for digital processing subsystem
  - ⇒ Acquisition, tracking and pointing requirements for satellite uplink

CHORD™ Prototype Design

- ~8% of the primary is obscured.
- Total weight:
  - ⇒ ~26 lbs (aluminum reflector, struts, mounts, housing, SLMS™ SAE, does not include gimbal or gimbal mount.)
- Not optimized for lightweight
  - ⇒ “Flightweighting” readily achievable
- Robust laboratory prototype instrument

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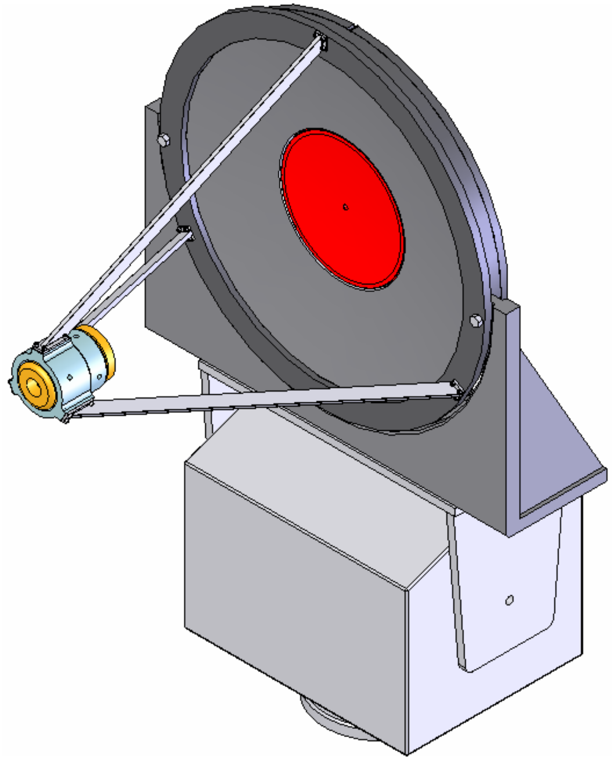

Conclusions

- Designed a 5/12 scale communications hybrid optical/RF dish.
  - ⇒ Design is frequency agile.
    - → Components are interchangeable.
    - → Can accommodate 1.55 micron lasercom with C, X, K, Ku, Ka, V RF bands.
  - ⇒ Design is robust.
    - → Easily assembled/disassembled and integrated.
    - → 6 DOF alignment capability.
    - → Gravity sag and random vibration acceptable.
  - ⇒ Design is traceable to lightweight flight configuration.
    - → Improved static and dynamic performance.